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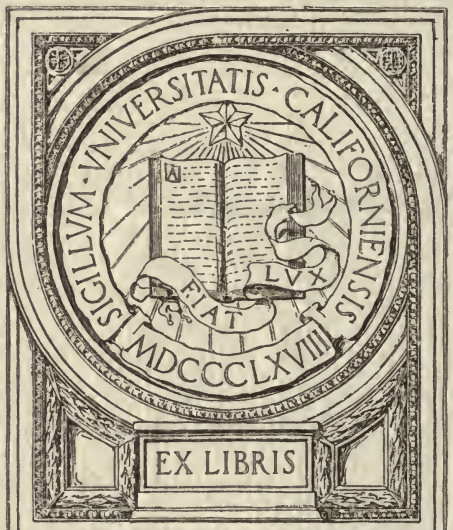
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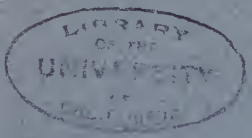
A THEORY OF GRAVITATION AND RELATED PHENOMENA

BY

W. J. SPILLMAN



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A THEORY OF GRAVITATION AND RELATED PHENOMENA.

By W. J. SPILLMAN.

Newton pointed out that if there there were a pressure in the ether about a body, and if this pressure diminishes as we approach the body, and if this diminution varies inversely as the distance from the body, gravitation would be accounted for. If, now, we can find some mechanism that will maintain a pressure in the ether like that just described, we can account for gravitation.

It can be shown that there is such a mechanism, if the following assumptions are granted.

Fundamental Assumptions.

The ether.—The ether is assumed to exist in the interstices of matter and in open space. It is assumed to be capable of distortion by finite force, and to oppose such distorting force with an equal opposite force. In other words, every point of the ether has a position which it normally occupies, and when removed from that position tends forcibly to return to it, the force being proportional to the distortion. It is further assumed that distortion at a given point in the ether tends to become distributed in the surrounding ether according to the law of inverse squares, and that such distribution occurs at a finite rate (the velocity of light).

The electron.—It is assumed that in the immediate vicinity of the electron there is a region of maximum permanent ether distortion, the distortion at other points in the surrounding ether varying inversely as the square of the distance from the center of the electron, and that pressures are transmitted at a higher velocity through distorted than through non-distorted ether.

The permanent distortion of the ether in the vicinity of the electron may be conceived of as a pushing back of the ether radially from the center of the electron, as if an impenetrable and

inelastic body were injected into the midst of an elastic body; or it may be conceived of as being circular, in two hemispheres facing each other, and opposite in direction in the two hemispheres.

In explaining the phenomena of inertia, electric currents, magnetism, chemical affinity, and radiant energy, the above alternative assumptions concerning the character of the distortion lead to essentially similar lines of reasoning, but the treatment on the assumption of radial distortion is very much simpler. For this reason it is used here. In the case of static electricity only the assumption of circular distortion, opposite in direction in the two kinds of electric elements, will explain the facts. The extension of the theory to static electricity is left for future treatment. It must be remembered, however, that the development of the theory on the basis of radial distortion differs only in detail, not in principle, from that on the basis of circular distortion.

The Atom.—The atom is assumed to consist, at least in part, of a Saturnian system of electrons in rapid orbital motion. It will be shown that such orbital motion, with the assumptions here made, would give rise to a pressure in the ether such as Newton showed would account for gravitation.

Physicists are agreed that the phenomena of inertia, the electric current, magnetism, and possibly also chemical affinity are probably related to each other in such manner that when we find the explanation of one of them this explanation will also throw light on the others. It will be seen in what follows that the theory of gravitation here presented appears also to offer suggestions as to the nature of these other forces, as well as a possible explanation of them.

Inertia.

Let *c*, Fig. 1*a*, be an electron stationary in the ether. At a certain undetermined distance from the center of this electron (equal to what we may call its radius) we may assume a maximum radial distortion of the ether, and we may regard the spherical shell at this distance as the surface of the electron. The distortion at this surface is a maximum with reference to

the distortion at greater distances, but not necessarily so for that at smaller distances. With the electron at rest, all distortion due to its presence is radial, and hence the resisting forces are all directed toward the center of the electron. If we imagine lines of position which would be straight lines radiating from the position of the center of the electron if the electron were absent, the only modification of these lines caused by the presence of the motionless electron would be to shorten them.

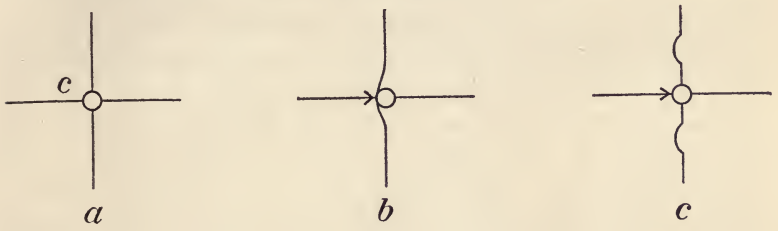

FIG. 1.

Suppose, now, that for a brief interval a force be applied to the electron tending to move it in the direction of the arrow in Fig. 1*b*. The ether in front of the electron now tends to be forced around behind it, and the lines of position perpendicular to the direction of the force are bent to the left (Fig. 1*b*). The bend in these lines would proceed outward wave-fashion, at the velocity of light. The bent condition of these lines corresponds to lateral distortion of the ether, which gives rise to forces tending to crowd the ether back in front of the electron, thus opposing the force tending to move the electron. This opposing force is identified as that due to the inertia of matter.

If, now, the moving force cease, the conditions in the ether about the electron an instant later are as shown in Fig. 1*c*. (Since the electron is now in motion, the lines of position change their position in the ether, for they are imaginary lines radiating from the center of the electron.) There being no longer any distorting force acting through the electron on the ether, the lines of position resume their normal form, first at the surface of the electron, and progressively later at greater distances, leaving a spherical shell of distortion moving outward as an ether wave with the velocity of light.

If, now, any force oppose the motion of the electron, the conditions shown in the vertical lines of position in Fig. 1*b* are reversed, the ether becoming distorted in such manner as to press the electron forward. Thus inertia opposes any change in the condition of rest or motion of a body.

Uniform Motion in a Straight Line.

When an electron moves with uniform velocity in a straight line, the only distortion of the ether about it is radial, and the lines of position radiating from it are straight. But since the amount of distortion varies inversely as the square of the distance from the electron, and since the distances between the electron and the points of the ether about it are changing, it follows that the condition of distortion is changing at every point in the surrounding ether. This means that every point of ether is moving, the motion being such as to maintain a constant condition of radial distortion about the moving electron. What is the character of the motion of a particular point of ether at any particular instant? A moment's consideration will show that the movement directly in front of the electron must be in the same direction as that in which the electron is moving. Directly abreast of the electron the motion of the ether must be in exactly the opposite direction. Also, the amount of motion of any point varies inversely as the square of the distance to the center of the electron. The direction of movement at other points may be found as follows:

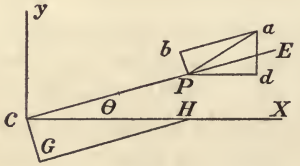

Fig. 2.

Let *C* (Fig. 2) be an electron moving in the direction *CX* with velocity (*V*=)*CH*. Let *CE* be any line passing through *C*. Then *GH*, parallel to *CE*, will represent *C*'s velocity in the direction *CE*, and *CG* will be *C*'s velocity in the direction *CG*,

perpendicular to CE. Let P be any point on the line CE. Let the ratio of the velocity (v) of P to the velocity of C be $1/R^2$. Then $v = V/R^2$. Since the velocity of P varies inversely as the square of CP, the ratio $1/R^2$ must do the same. Let Pb = the component of P's motion perpendicular to CE, and ba = the component parallel to CE. Then Pa = the velocity of P, and shows the direction of motion of P. Furthermore, the angle $aPE = PCX = \theta$. Hence the angle $aPd = 2\theta$. But 2θ is the angle which the tangent to a circle makes with the axis of X when this circle has its center on the axis of Y, and its circumference passes through the origin, as seen in Fig. 3. Here the

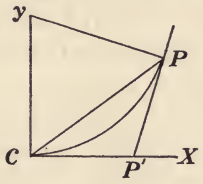

FIG. 3.

angle $P'PC = P'CP = \theta$, and $PP'X = P'CP + P'PC = 2\theta$. Hence the direction of motion at every point in the ether about C is tangent to circles whose centers lie in the plane CY (Fig. 3), and whose circumferences pass through C and through the points in question. Thus, the direction of motion at any instant in the ether about a moving electron is in exact circles. These circles are all tangent to each other at C, their centers lie in the plane CY,* they are of all diameters from O to ∞, and they lie in every possible plane passing through CX (Fig. 3).

Electrical Attraction.

Let a and b, Fig. 4, represent two electrons moving parallel to each other. In the arcs aPb the motion which a tends to set up is opposed by the motion which b tends to set up. Hence there will be pressure generated in these arcs, and in a direction tangential to them. But such pressure tends to move the ether toward the right.† There is thus pressure generated to the

* That is, in the plane produced by the revolution of CY about CX.

† See paragraph one under Gravitation, beyond.

right of these arcs, while a partial pressure vacuum forms behind them. The ether pressure between the electrons is thus reduced, and the electrons are driven toward each other by the greater

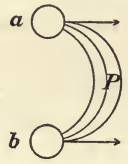

FIG. 4.

pressure on their distal surfaces. This represents the conditions existing in two parallel currents of electricity, and is offered as an explanation of the attraction between them.

Electrical Repulsion.

In Fig. 5, let a and b represent two electrons moving in opposite directions. Let P represent a point in the ether midway

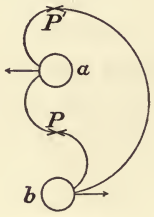

FIG. 5.

between them, and P' a point on the opposite side of one of them from the other. Electron a tends to move the ether to the right at both P and P'. Electron b tends to move it in the opposite direction. Hence pressure is generated at both points. But the pressure at P' is smaller than that at P in the inverse ratio of the square of the distance from b. Not only that, but the pressure at P' is away from both electrons. We thus have increased pressure in the ether between the electrons, and decreased pressure in the ether on their outer sides. Hence they are driven apart. This seems to be the explanation of electrical repulsion in parallel circuits in which the currents are flowing in opposite directions.

Induced Currents.

Let L and L', Fig. 6, represent parallel portions of two closed circuits. B is a battery arranged to send current through L. Let the arrow show the direction in which the electrons move in this current. When the circuit L is first closed, a stream of

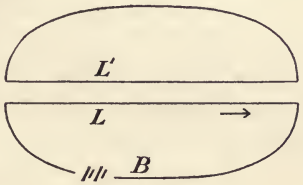

FIG. 6.

electrons passes into L. This sets up motion of the ether in L' toward the left. This movement of the ether creates stresses against the electrons in L', tending to drive them toward the left, thus giving rise to a counter induced current. Any increase of current in L will similarly cause an inverse current in L'.

After the current becomes constant in L, the following conditions obtain: because of resistance in the conductor, force must be exerted on the electrons to keep them moving. This force originates in the generator (battery or dynamo), and is propagated along the conductor much as pressure is in a gas, utilizing the mutual repulsion of the electrons. Because of this urging force (electromotive force), the inertia of the particles is brought into play and a state of stress in the ether about the conductor is produced similar to that shown in Fig. 1*b*. In other words, the ether about the conductor is displaced in a direction opposite to that in which the electrons move. The energy which will oppose stoppage of the current is thus stored up in the stressed ether about the conductor.

If, now, the current in L diminish, the stress in the ether is reduced, and an impulse moves off into space causing a slight movement of the ether in the direction of the current; that is, the bent ether partly unbends. Free electrons in L' are thus given an impulse in the direction of the current in L, giving rise to a direct current in L'.

The phenomena of electric currents indicate that there are electrons in and about the atoms of conductors that are not integral parts of these atoms. These semi-free electrons are probably held in the vicinity of the atoms by attractions exerted by the atoms. Possibly they are vibrating back and forth through the atoms, or revolving about them. A surge in the ether would carry certain of these electrons out of the sphere of action of one atom into that of another. But these electrons would enter the sphere of the new atom with sufficient velocity to carry them beyond to another atom. An electric current may thus be pictured as a series of electrons swinging from one atom to another in a conductor. This, of course, is only a suggestion as to the nature of the electric current, which may or may not represent the facts correctly.

Magnetism.

An electron moving in a closed orbit, as is supposed to be the case in atoms, would, under our assumptions, cause every point of ether about it to move in a similar but smaller orbit, the form of the orbit of any point depending on the orientation of the

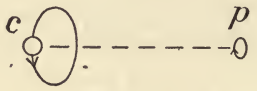

FIG. 7.

point with reference to the orbit of the electron. In Fig. 7 the movement of electron *c* counterclockwise in its circular orbit causes the point of ether *p*, lying on the axis of *c*'s orbit, to move clockwise in a similar smaller orbit. In all cases, the movement of the ether about an atom would be perpendicular to the familiar lines of force in the magnetic field of the atom.

Similarly, the passage of an electron through a long, straight portion of a conductor would cause the points of ether about the conductor to describe approximately circular but extremely small orbits, the plane of each orbit passing through the conductor. Here again the ether movement is perpendicular to the lines of force in the magnetic field about the conductor.

Superposed magnetic fields would give rise to changes in the static pressure in the ether, raising it where the fields are opposed, and lowering it where they coincide in respect to the ether movements in each. Magnetic attraction and repulsion may thus be accounted for.

That the strength of the magnetic field about an atom varies inversely as the cube of the distance from the atom is proven as follows: Let D represent the distance of the point c (Fig. 8) from the proximal side of the atom (*i. e.*, from electron a) and d the diameter of the atom. Let m represent the motion which a tends to produce at c, and n the motion which b tends to produce at the same point. Then

$$m = \frac{K}{D^2}, \text{ and } n = \frac{K}{(D+d)^2}, \ K \text{ being a constant.}$$

$$\therefore m - n = \frac{K}{D^2} - \frac{K}{(D+d)^2} = \frac{2KDd + Kd^2}{D^2(D+d)^2} = \text{the strength of}$$

the field at c. But d vanishes with reference to D at ordinary distances. Hence

$$m - n = \frac{2KDd}{D^4} = \frac{2Kd}{D^3}.$$

Hence the strength of the magnetic field about an atom varies inversely as the cube of the distance. This is consistent with experimental results, for the combined effect of the two poles of a short magnet on another single magnetic pole is known to vary inversely as the cube of the distance. This law does not hold for small distances, such as we may suppose are concerned in chemical affinity. At the point where $D = d$, $m - n$ becomes equal to $3K/4D^2$. Hence, at that point the magnetic field varies inversely as the square of D.

Gravitation.

In developing a theory of gravitation from the assumptions with which we began, it is necessary for the reader to recall a familiar fact that must be used. Suppose a ring imbedded, say, in a matrix of cement. Now, if the circumference of the ring

be increased, as it would be by raising its temperature, the ring will press outward against the matrix. This outward pressure arises from a tangential pressure in the circumference of the ring. In general, a tangential pressure in an arc will give rise to outward pressure in the direction of the convexity of the arc.

In Fig. 8, *A* represents an atom, consisting of a Saturnian system of electrons, revolving as shown by the arrows.

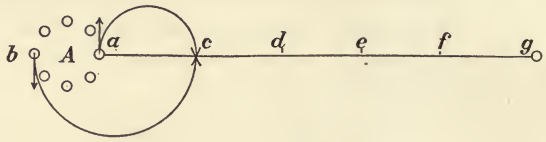

FIG. 8.

Electron *a* tends to move the ether downward at *c*, *d*, *e*, *f*, and *g*; *i. e.*, at all points along the line *ag*, and the velocity at any point tends to vary inversely as the square of the distance from *a*. Electron *b* tends to move the ether upward at all these points. Hence pressure is generated at each of these points. Since the movement of the ether is in the arcs of circles, concave toward the atom, these pressures are propagated outward, or away from the atom. Thus the pressure generated at *c* extends outward from *c* indefinitely. At *d* the pressure generated at *d* is added to that generated at *c*, so that beyond *d* the pressure is the sum of these two pressures. More generally, the total pressure at any point is the sum of all the pressures generated between that point and the atom. Hence the static pressure in the ether is greater the farther we get from the atom. Let *g* represent an electron floating in the ether. Now the static pressure in the ether on the distal side of *g* is greater than on the proximal side. Hence *g* is driven toward the atom. This is taken to be gravitational attraction. To show that this force varies inversely as the square of the distance from the attracting body, we have the following considerations. The amount of pressure generated at any point along the line *ag* varies inversely as the square of the distance of that point from the electron *b*, since *b* is more distant than *a*, and the amount

of pressure generated is limited by the smaller motion which b tends to give the ether. Therefore $P = K/D^2$, where P is the pressure generated at the point under consideration, K a constant, and D the distance of the point from electron b. We may represent this equation graphically, as in Fig. 9, where the

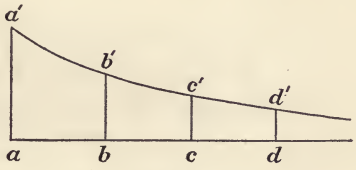

FIG. 9.

ordinates aa', bb', etc., represent the respective pressures generated at the points a, b, etc. It is plain that the total pressure existing, say at the point d, is represented by the area $abcdd'c'b'a'$; *i. e.*, the area included between the curve and the axis of X. Now this area is

$$A = \int ydx = \int \frac{K}{D^2}\, dD = C - \frac{K}{D}.$$

Referring to Newton's description of the pressure required to account for gravitation, we see that the expression $C - K/D$ exactly fits that description. (See p. 1.)

When D becomes indefinitely great in this equation we have $A = C$. Hence C is the ether pressure at an indefinitely great distance from the attracting body. K/D is plainly the pressure generated *beyond* the distance D. That is, the total pressure at distance D is equal to the pressure at infinite distance minus the pressure generated beyond distance D. This is equivalent to stating that the pressure at any point is the sum of all the pressures generated between that point and the body producing these pressures.

Let d equal the diameter of an electron and D the distance of the proximal side of the electron from the attracting body. Then the pressure on the proximal side of the electron is $C - K/D$ while that on the distal side is $C - K/(D + d)$. The difference between these pressures is

$$\frac{K}{D} - \frac{K}{D+d} = \frac{K(D+d) - DK}{D(D+d)} = \frac{Kd}{D(D+d)}.$$

But d vanishes with respect to D; hence this expression becomes Kd/D^2 for ordinary distances. That is, gravitational attraction, at sensible distances, varies inversely as the square of the distance from the attracting body.

From what has been said of gravitational force it is seen that a body which floats in space near another body is acted upon by gravitational force in much the same way as a bubble is driven upward in water. It is in a medium in which the pressure increases outward from the attracting body. It is thus driven inward toward the body. The bubble is pressed upon below with a stronger force than it is above, and is hence driven upward.

Mass.

If the assumptions as to the meaning of motions and stresses in the ether and the reasoning above are correct, it is seen that the gravitational attraction *which a body exerts* depends not only on the actual mass of the body but upon the Saturnian structure of the atom and the velocity with which the electrons move. Hence, if I am correct, we must distinguish between mass as measured by the attraction of other bodies—that is, by inertia—and mass as measured by attracting power. The former depends only on the number of electrons present, and is absolutely invariable for a given quantity of matter. On the other hand, the attracting power which a body exerts may vary between wide limits, if the velocity of its electrons changes. If I am correct, then, Newton's law of gravitation needs to be restated. According to Newton, every particle of matter in the universe attracts every other particle with a force varying as the product of the masses of the two particles and inversely as the square of the distance between them. This law is true only of the attraction which one body exerts on another, and then only when the mass of the attracting body is measured by its attracting power, while the mass of the attracted body is measured by its inertia. I would state this law thus: every atomic body in the universe attracts every other body (whether

atomic or not) with a force which varies inversely as the square of the distance, and directly as the product of the inertia of the attracted body by the amount of internal energy in the atoms of the attracting body.

Newton believed, and stated very positively, that the attraction which two bodies exert on each other does not consist of two separate attractions, but that it is one and the same attraction. From what we have seen above, unless there is some flaw in the course of reasoning followed, the attraction which two bodies exert on each other must be considered as two distinct and independent forces. As already stated, Newton described a pressure which, if it could be shown to exist in the ether, would account for gravitation. Granting my fundamental assumptions, I have shown that such a pressure does exist. But the very pressure described by Newton does not call for gravitation to be mutual. On the other hand, it makes two separate and independent forces of the attraction between two bodies.

If my reasoning is correct, the mass of the earth which the sun attracts is not necessarily equal to the mass of the earth which attracts the sun. The attracted mass depends only on the number of electrons in the attracted body. The attracting mass depends on the number and arrangement of these electrons and on their orbital velocities.

It seems clear from the above that when a body is drawn toward another body by gravitational attraction, the energy of motion which the attracted body gains must be deducted

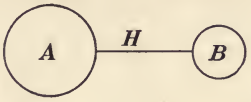

FIG. 10.

from the orbital energy of the electrons in the atoms of the attracting body. The attracting body is not itself drawn toward the attracted body because of its own attraction; it merely loses atomic energy as the attracted body approaches. Let us consider what would happen in a system like that shown in Fig. 10, where A represents the attracting body, B the attracted body

(which itself exerts no attraction) and H a rigid connection between A and B. Here A acts on the ether in such manner as to generate pressure at all points in the ether, the total amount of this pressure at any point being $C - K/D$. This pressure is greater on the distal than on the proximal side of B, and hence would set the whole system in motion. But all the energy of motion thus acquired would be deducted from the internal energy of A, and hence would weaken by so much the attracting power of A. The system would tend to convert all this energy in A into energy of motion of the whole system, after which it would move at constant velocity.

The idea that gravitational attraction is mutual, and that the force which draws one body, A, toward another body, B, is one and the same with the force that draws B toward A, involves a theory as to the nature of the stress causing gravitational force, namely, that gravitational force is due to distortion of the ether, which, in consequence, acts like a bent spring, while the greater the distortion, the less the force it exerts The ether pressure which Newton described so accurately, and which I have accounted for, granting, of course, my fundamental assumptions, *does not call for mutual attraction.* Newton did not follow out to its logical conclusion his own suggestion of an ether pressure, because at that time there was no possible way of accounting for it. Had he done so, he would certainly have discovered that, if gravitation is due to such a pressure, it is not mutual.

Newton's generalization to the effect that gravitational force is proportional to the product of the masses concerned was also an unsupported assumption. On this point J. E. Mills, in his excellent treatment of this subject in the *Journal of Physical Chemistry*, May, 1911, remarks: "When Newton proposed his magnificent generalization he had *no proof whatever* that gravitational attraction did vary as the product of the masses of the attracting bodies."

Mills further calls attention to the fact that the masses of celestial bodies have all been calculated *on the assumption that Newton's law is true.* I have shown here that gravitational attraction is not mutual (granting, of course, my fundamental assumptions). My formula, developed directly from my funda-

mental assumptions, is very similar to that given by Mills. My statement of the law of gravitation (see p. 12) is expressed by the formula

$$F = \frac{MM'}{D^2},$$

in which F represents the attraction A exerts on B, M is the mass of B, D the distance between them, and M' is a factor depending on the energy represented by the orbital motion of the electrons in the atoms of A. Mills's formula for the attractive force which a body can exert is

$$\text{Force} = \frac{\mu M}{S^2},$$

where M is the mass of the attracting body, S the distance to the attracted body, and μ is "an intensity factor." (The mass of the attracted body is omitted in this formula, for reasons given by Mills.)

There are several important points of difference between my conclusions and the ideas advanced by Mills, but I believe these can all be harmonized. To do so here, however, would require too much space. I will call attention to only one of these differences.

Mills states (p. 455) that mass is "proportioned to the attractive forces to which the body is subjected." This is true in the sense that the amount of inertia a body will display is proportional to these forces. I find two kinds of mass. One of these depends on the volume of ether displaced by the electrons of a body. This kind of mass is measured by weight; *i. e.*, by the attractions which other bodies exert on the body. It is the omitted mass of the attracted body in Mills's formula. The other kind is a function of the internal energy of the atoms of the body. It depends not only on the volume of ether displaced (the M of Mills's formula), but on the energy of motion of the electrons in the atoms (the μ factor in Mills's formula).

According to my theory, when a body is raised from the earth, the apparent potential energy which it gains is not stored in the ether as some impossible kind of stress, as is generally

assumed to be the case. (In this connection Mills quotes Farady as repeatedly asserting his belief that no force with the properties usually ascribed to gravitation could exist. On my theory no such paradoxical assumptions are necessary.) The energy which appears to be potential energy of the raised body is, on my theory, simply added to the energy represented by the orbital motion of the electrons in the earth's atoms. When the body falls again, this energy is transferred from the earth's atoms to the falling body *by means of the ether*. When the body strikes the earth this energy is converted into heat.

There is another striking parallel between my conclusions and those of Mills. He concludes that the amount of *gravitational force* which a body can exert is limited and definite. My conclusion is that *the amount of energy of motion* which a given body can generate by attraction on other bodies is similarly limited and definite. All the energy of motion thus generated, according to my view, is deducted from the internal energy of the atoms of the attracting body. When this supply is exhausted, the body no longer exerts attraction. It is suggested elsewhere in this paper that this may be the condition of comets, and that this fact may account for their disintegration, as well as for their apparent lack of attracting power.

The phenomena of falling bodies prove the attraction is proportional to the mass of the *attracted* body; and this is what my theory calls for. But these phenomena do not prove that the force is proportional to the mass of the *attracting* body. On my theory, the attraction is proportional to the mass of the attracting body only so long as the *internal energy of the atoms of the attracting body remains the same.* There are no known facts not in accord with this conclusion.

Direction of Attraction.

On the theory here presented, the direction in which gravitational force tends to move an attracted body would be wholly independent of any motion which the attracted body might have. If the attracting body were stationary in the ether, that is, if its attracting center were stationary, all bodies would be attracted exactly toward this center, no matter what motions

the attracted bodies might have. But if the attracting body itself is in motion, then the attracting center will be somewhere on the locus of the real center of the attracting body, behind the real center. In this connection Drude remarks:* "One can indeed deduce the general result, that by acceptance of the latter (*i. e.*, the effect of the sun's motion through space, if gravitational force is propagated at a finite velocity) anomalies in the motion of the perihelion of the planets may be explained." Newton stated that a perihelion motion arises if one introduces, instead of the square, a somewhat different power of the distance, and Hall has shown that an exponent 2.00000016, instead of 2, will account for the perihelion movement of Mercury.† From what has been said above it seems probable that attraction is not directed exactly toward the center of the attracting body when the latter is in motion, but rather to a point occupied by this center shortly before.

It is also possible that there is a sensible variation from the law of inverse squares. In the first place, the formula for gravitational pressure is arrived at by omitting certain infinitesimal terms, which make the exponent of D a little greater than 2. This excess, however, is exceeding small, and may not produce measurable effects in long periods of time. We could calculate it if we knew the diameter of the electron.

Pressure in the Ether.

Depending on the correctness of the fundamental assumptions on which the present theory is based, it has been shown that there is a mechanism by which the atom maintains an "even-powered" pressure in the ether about it. The magnitude of this pressure might possibly be calculated; but to do this it would be necessary to know the diameter and velocity of the electrons, the size of their orbits, and the rate at which pressures are propagated through the ether. I have calculated the pressure which the electrons of an atom of iron could maintain if they moved as do the molecules of a gas, with a velocity of 12,000 miles per second, in a space equal to the volume of the iron

* *Ann. d. Phys. & Chem.*, Vol. 62.

† Smithsonian Rep., 1876, p. 205.

atom. The value of this pressure is 10^{19} dynes per square centimeter. The pressure caused by a single atom under my theory of gravitation cannot exceed this, for this pressure was calculated on the assumption that the total kinetic energy of the electrons is utilized in maintaining this pressure. How much smaller the actual pressure is is uncertain; but it would probably be much smaller. Yet it is seen that a single atom may possibly generate in the ether about it an enormous pressure. When it is remembered that every atom in the universe generates such pressure, the sum of all these pressures is beyond comprehension. The theory certainly provides pressure sufficient to account for the phenomena of gravitation.

Chemical Affinity.

It has been shown (p. 9) that the formula for the strength of the magnetic field about an atom is $(2KDd + Kd^2)/[D^2(D+d)^2]$.

The gravitational force generated at the same distance is $K/[(D + d)^2]$.

Equating these two values we have

$$\frac{2KDd - Kd^2}{D^2(D + d)^2} = \frac{K}{(D + d)^2}. \quad \therefore \quad D = (\sqrt{2} + 1)d.$$

That is, at the point at which $D = (\sqrt{2} + 1)d$, the magnetic field is equal to the gravitational force generated. There is thus a point at which two atoms, properly oriented with reference to each other, would be in a position of equilibrium, being repelled from each other by magnetic force, and pulled toward each other by gravitational force. We may have here a hint as to the nature of chemical affinity.

Relation of Molecular Attraction (cohesion) to Distance.

It is known that to increase the distance between the molecules of a homogeneous liquid by a given fraction of itself, the amount of heat energy necessary is proportional to the mass of the liquid.

Let A represent the attraction between two molecules at unit distance from each other. Assume the law of relation between this attraction and distance to be such that the attraction

between two molecules at distance S varies as some power of S (whether directly or inversely to be determined later). The attraction at distance S then becomes AS^x, where X is to be determined. In overcoming this attraction by moving one of the molecules through a distance nS, the energy expended is

$$\int_S^{nS} AS^x dS = \frac{AS^{x+1}}{x+1}(n^{x+1} - 1),$$

which may, for convenience, be written KS^{x+1}, since n and x are constants.

Now, the number of molecules at distance S from a given molecule is proportional to S^2. Hence, the energy required to move an elemental spherical layer of molecules, at distance S from a given molecule, is

$$KS^{x+1} \times K_1S^2 = K_2S^{x+3}.$$

The total energy required to overcome the attraction of a single molecule at the center of the body for all the elemental layers concentric about it is evidently

$$\int_o K_2S^{x+3}dS,$$

where R represents the radius of the body, which, for convenience, is assumed to be spherical. This integration gives $K_2R^{x+4}/x + 4$, which may be written K_3R^{x+4}. Now every molecule in the mass, except a negligible number near its surface, exerts attractions which require like amounts of energy to overcome. The total number of molecules about which such a field of force exists is proportional to the volume of the sphere and may, therefore, be represented by K_4R^3, where K_4 is a constant, and R the radius of the sphere. The total energy required to expand the body is, therefore, $K_3R^{x+4} \times K_4R^3 = K_5R^{x+7}$. But we know that this is proportional to the mass, and hence to the volume of the sphere. Hence $K_5R^{x+7} = K_6R^3$. Since R may have any value, let $R = 1$. Then $K_5 = K_6$, and $R^{x+7} = R^3$. $\therefore x + 7 = 3$. $\therefore x = -4$. Hence, the force of attraction between neighboring molecules appears to vary inversely as the fourth power of the distance.

Can this force be identified with any of the forces found in the development of the foregoing theory? I believe that it is not inconsistant with these forces. According to the theory, the atom is a magnet. It has been suggested that the phenomena of chemical affinity are due to this property of atoms. Now if two atoms be properly placed with reference to each other, each tends to cancel the magnetic field of the other. Yet two atoms can not entirely cancel each other's fields. There is thus a magnetic field about a molecule which may be looked upon as a "left over" from chemical affinity. In Fig. 11,

FIG. 11.

let a and b represent two atoms so placed as to be in equilibrium; in this position they tend to cancel each other's magnetic field. Let P represent a point in the ether in the vicinity of the molecule ab. Let D represent the distance of P from b, and $D + d$ its distance from a. Now, b's magnetic field at P may be represented as K/D^3, since it varies inversely as the cube of the distance. Similarly, the strength of a's field at P is $K/[(D + d)^3]$. The resultant strength of field at P is, therefore,

$$\frac{K}{D^3} - \frac{K}{(D + d)^3} = \frac{3D^2d + 3Dd^2 + d^3}{D^3(D + d)^3}.$$

If d is small in comparison with D, this becomes

$$\frac{3D^2d}{D^6} = \frac{3d}{D^4}.$$

Hence the magnetic field about a chemically saturated molecule varies inversely as the fourth power of the distance. Thus we find a force varying with distance as does the molecular force considered above.

There is the further fact to be considered that a magnetic field is modified by the presence of other magnetic bodies. Hence it is possible that the magnetic field of a molecule sur-

rounded by other molecules may extend only a short distance, a fact which may have something to do with the rapid decrease of molecular force as the distance increases.

Possible Relation Between Temperature and Gravitational Attraction.

It has, of course, long been known that weight is independent of the temperature of the weighed body. But if the theory of gravitation here presented is true, there is a *possibility* that the temperature of a body may be a factor in the gravitational force it exerts. This would be the case if there is any exchange of energy between the internal energy of the atom, represented by the revolution of the electrons in a Saturnian system, and the heat energy of the atom, represented by its motion as a whole. This relation, however, cannot be a direct one, as the following considerations will show:

It is estimated that the electrons in an atom under ordinary conditions move with a velocity of about 14,000 miles per second. The amount of internal energy in the atoms of a pound, say of copper, would thus be $(1/2MV^2$ poundals, or) 11×10^{13} ft. lbs. Assuming that the specific heat of copper between 0° C. absolute and 300° C. absolute is .091 (it is probably less than this), the total heat energy in a pound of copper at ordinary temperatures is about 38,000 ft. lbs. The former number is a little less than 3 thousand million times the latter. Hence, if we double the absolute temperature of the copper, and if all the energy thus added were converted into internal atomic energy, the increase in this internal energy would be infinitesimal, and not capable of measurement.

But if we imagine the internal energy of the atom to be reduced by some means to a very low point, then an increase in temperature might produce a perceptible effect on the gravitational force exerted. Such an assumption would explain a very puzzling phenomenon exhibited by comets. We may assume these bodies to be extremely cold; also that this condition has existed in them for ages. Under such conditions there is a possibility that atomic collisions may have transformed a considerable portion of the internal energy of the atoms into heat, and that this heat has

become dissipated by radiation into space. The matter composing a comet would in this way lose much of its gravitational force. These bodies are known to consist of flocks of meteorites; possibly they are disintegrated planets or satellites of our own or of formerly existing stellar systems. As they approach the sun they first expand and then contract in size. Thus, Enke's comet is 300,000 miles in diameter when at a distance of 130 million miles from the sun, but contracts to a diameter of only 10,000 to 14,000 miles at its perihelion distance of 33 million miles. If we may assume the temperature of this body to be very near the absolute zero at its aphelion, then the increase in temperature on approaching the sun must be relatively large. Now, if a considerable portion of this heat energy is converted into internal energy of the atoms, then the increase in gravitational force resulting might account for the diminution in size of the comet.

It may also be suggested here, though it has no relation to the theory under discussion, that the increased frequency of collision between the particles of a comet as the comet contracts may give rise to the cometary tail by thus freeing small particles of dust and the like adhering to the meteorites composing the body of the comet.

If, when a body becomes cold, and remains so for countless ages, the internal energy of its atoms may, by being slowly converted into heat, become dissipated, our theory offers an interesting explanation of a self-perpetuating universe at all times similar to that which we know. As the central body of a system loses its power of gravitational attraction its satellites gradually increase their orbits and lose in velocity, finally giving a widely scattered group of bodies of slight motion relative to their former center of attraction. Finally, because of rotation on their axes, all these bodies, including the central one, become disintegrated into meteorites, which ultimately scatter throughout the universe. The smaller bodies, with presumably smaller rotational velocities, disintegrate more slowly than the larger, and thus persist longer. They thus have more chance of being drawn into other systems as comets, before they become completely scattered as single fragments. Occasionally the larger

bodies, before complete disintegration, meet similar meteoric groups, the heat generated by collision setting up attraction anew, thus giving rise to new attracting centers which develop planetary systems about them from the fragments of two former systems.

We have been repeatedly told that space is filled with "dark" stars—dead suns that have lost their heat. Perhaps, after all, this is not the case. Such bodies may be only temporary; they may soon disintegrate and scatter out through space as meteorites. The heat energy thus dissipated into space may be in large part absorbed by other bodies, in the manner in which an incandescent gas absorbs rays of the same length it emits. If such is the case, then there is not necessarily any permanent loss of energy by dissipation into space, and the universe thus becomes self-perpetuating.

Periodicity of Sun Spots.

It has been known since 1851 that the time between maximum sun spot periods is roughly equal to the period of revolution of the planet Jupiter. If the present theory of gravitation is correct, it suggests an explanation of this phenomenon. When Jupiter is in perihelion it is approximately 46,000,000 miles nearer the sun than when in aphelion, and has a correspondingly greater velocity. The increased energy represented by this increased motion is assumed to be derived from the internal energy of the sun's atoms. If this is true, the velocity of the electons in the sun's atoms must be smaller when Jupiter is in perihelion than when she is in aphelion. Hence, when the planet is in aphelion, there is a possibility that the greater velocity of the electrons in the atoms of the sun causes a greater degree of atomic degradation of the nature of that seen in radium, and related radio-active substances. It is reasonable to suppose that this would affect the sun's electrical activity. Thus, the approach of a planet toward the sun would tend to decrease this activity, while it would increase as the planet recedes.

Assuming that the approach or recession of a planet does cause corresponding changes in the electrical activity of the sun by

decreasing or increasing atomic degradation, Mr. J. W. Froley and the writer have calculated the relative effects of all the planets on the sun's electrical activity. The effects, if any, produced by Jupiter and Saturn are so large when compared with those of all the other planets combined that the latter may be neglected. Fig. 12 shows the relation between sun spot frequency and the combined effect of Jupiter and Saturn, on the assumptions here made. The nearly regular curve represents the combined effect of the two large planets, while the less regular curve shows sun spot frequency. There is at least a remarkable coincidence in these curves. It will be noticed that

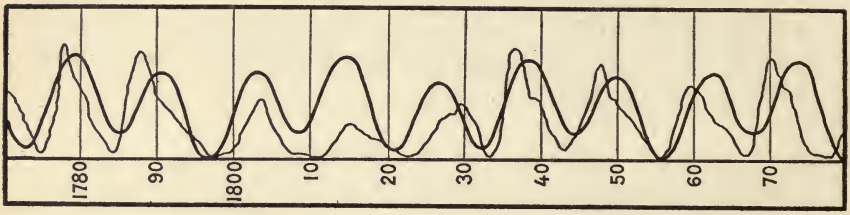

FIG. 12. Relation of sun spots to combined action of Jupiter and Saturn on the sun. The smooth curve represents the combined effect of the two planets; the less regular curve, the frequency of sun spots.

in 5 of the 10 sun spot minima shown in Fig. 12, the sun spot minimum occurs just before the close of the period of rapid decrease of activity. These are the sun spot minima occurring about the years 1784, 1843, 1855, 1867, and 1878. Each of these 5 minima is succeeded by a maximum which occurs at the time of most rapid increase in activity. In the other 5 cases, namely, in 1775, 1797, 1810, 1822, and 1833, the sun spot minimum occurs just after the minimum activity is reached, and, with only one exception, the succeeding sun spot maximum occurs very nearly at the time of maximum activity.

If it is true that the eccentricity of the orbit of these two great planets is the cause of sun spot periods, is it not possible that the variability of some stars may be similarly accounted for? Should a star have several relatively large attendants, each with a highly eccentric orbit, the resulting variations of electrical activity might not only be considerable, but the curve

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of variability would be very complex. A proper analysis of such a curve could be made to reveal not only the number of the attendants concerned, but their time of revolution about the star.

There is reason to believe that there is actually a relation similar to that here predicated between sun spots and electric activity on the sun.

The writer desires to express his obligation to Mr. J. W. Froley, whose constant advice on mathematical phases of the theory has been exceedingly helpful; also to Dr. W. J. Humphries, who has read the manuscript, and offered helpful suggestions in the treatment of some of the problems connected with the working out of the theory.

Conclusion.

A theory which offers a rational explanation of hitherto unexplained phenomena is useful for two purposes. In the first place it enables the student to see how a thing *may* be caused, and thus renders intelligible what before was only a jumble of apparently unrelated facts. It helps the mind in forming a conception of facts. It is, of course, unnecessary to caution the wise teacher that any unproved theory should be presented *as* a theory, not as a fact. In the second place, a good theory usually illuminates new fields, and points to hitherto unknown facts. Such a theory suggests new investigations, and herein lies the principal value of a working theory. Unfortunately, the present theory, while it points to many new facts, reveals nothing which is certainly within the reach of experiment. There is, however, one possible direction in which experiments might reveal something of interest. Different elementary substances, such for instance, as lead and copper, which differ greatly in atomic weight, might possibly differ also in the gravitational attraction which a given mass of the two substances exerts. This depends on whether the internal energy of the atom is proportional to its mass alone, and on whether attracting power varies directly as this internal *energy*, or as some other function of the *velocity* of the electrons in the atom.

It may be, also, that a freshly fallen meteorite might differ in its attracting power from a terrestrial body of the same weight.

It is hardly necessary to point out that the kind of ether presupposed in the present theory is consistent with the phenomena of light and other forms of radiant energy.

It may also not be out of place here to suggest that the "ether drift," if it occurs as here supposed, might possibly be detected by measuring the wave length of light transmitted in *different directions* at the same time and place.

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